CERN-KEK **Collaborative Activities for Linear Colliders**

Steinar Stapnes – consulting with Shinichiro Michizono and Akira Yamamoto

2019-20 – a few examples:

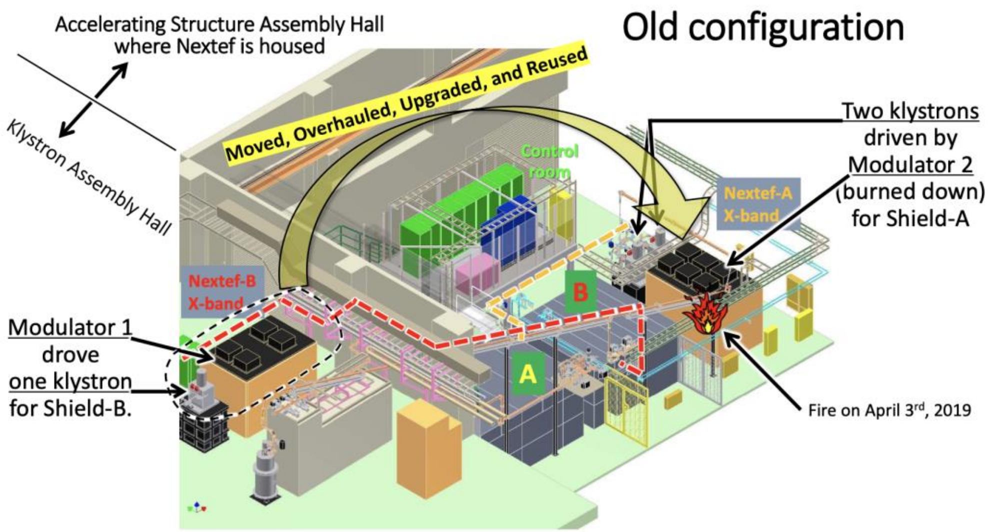
- X-band facility and industrial studies
- HiEff klystron:
  - Superconducting solenoid, for high-efficiency klystrons
- Nano-beam technology
  - Nano-beam studies a common subject for ILC and CLIC, using ATF-2

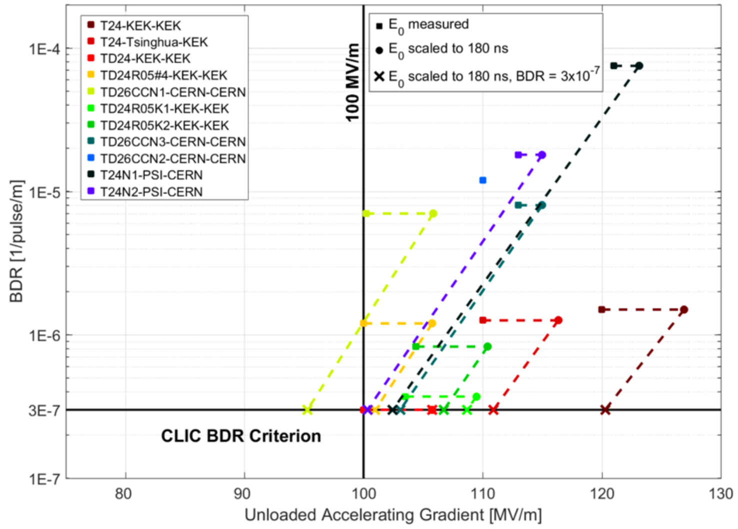
2020-21:

- New basis for common work established: CERN LC planning after the ESPP and the ILC IDT startup
- CERN – KEK new addendum for ILC-IDT
- Examples of activities – continuing, established or possible

Conclusion

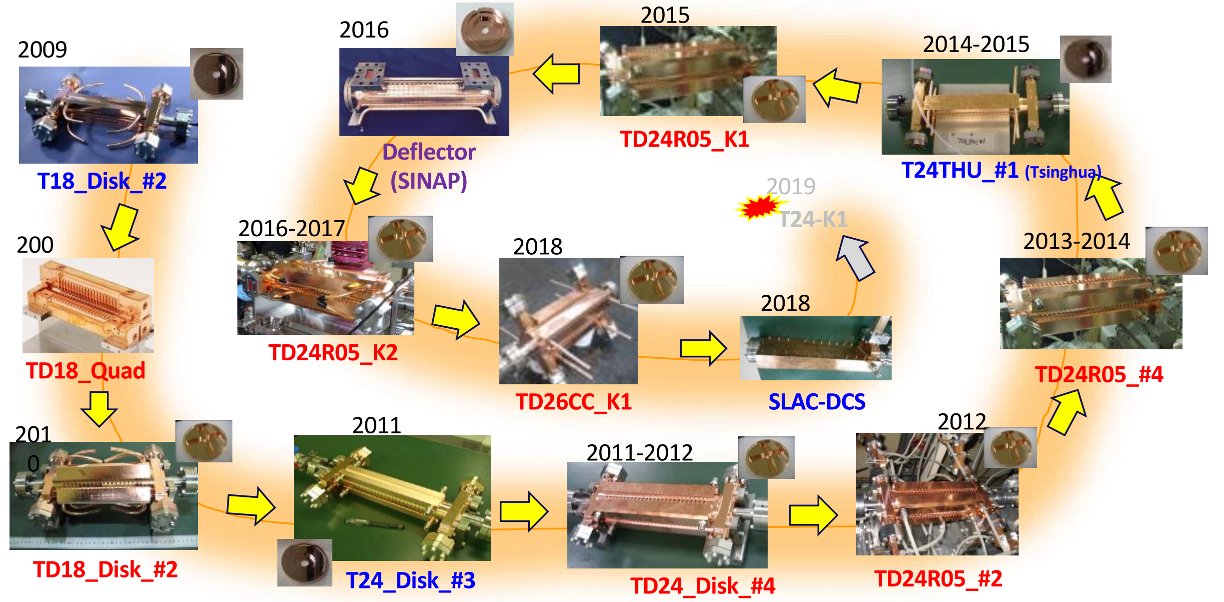
NEXTEF: New X-band Test Facility (11.4 GHz)





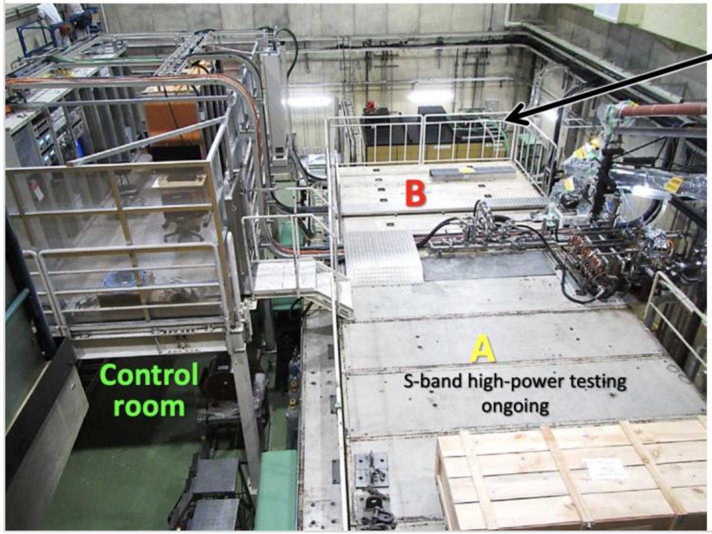
X-band Prototype Structures Tested at Nextef

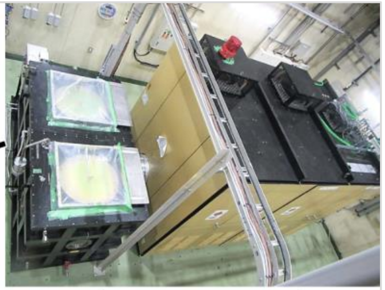
T18 →Quad → TD18→T24→TD24→TD24R05→TD24R05 →T24THU→TD24R05 →Deflector →TD24R05 → TD26CC → DCS → T24-K1 (terminated by the fire)



Aug. 2020

Current Snapshot (1/2)



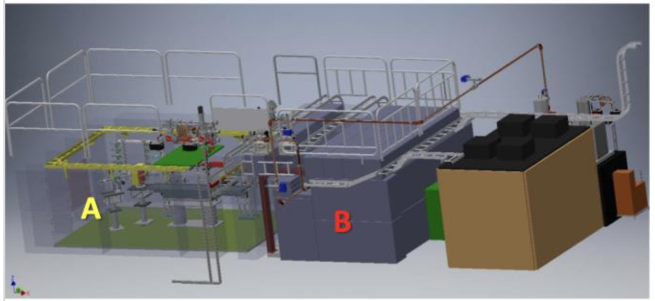


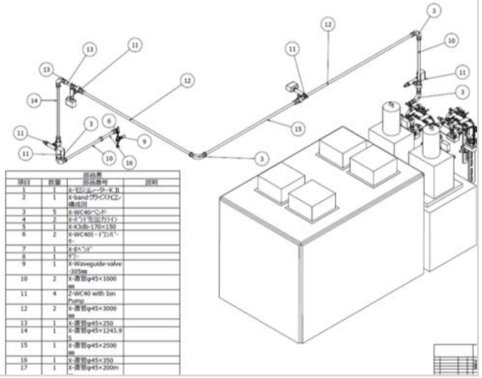
↑ Oil tank with any klystron not yet installed

↑ X-band Modulator

Work to be performed within this JFY (by Mar. 2021)

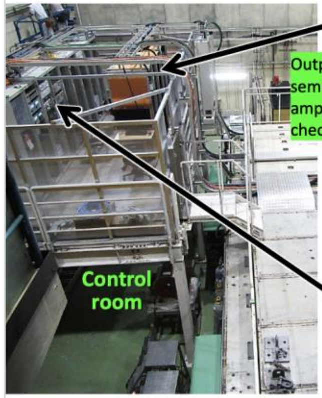
1. Fabricate power line of waveguides from the klystron to Shield-B
2. Reboot the vacuum system
3. Install the klystron
4. Re-construct LLRF and DAQ systems





Aug. 2020

Current Snapshot (2/2)



Output from the semiconductor amp. already checked

For the X-band high-power source

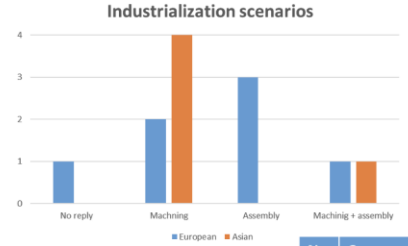
Rad. Safety System in operation

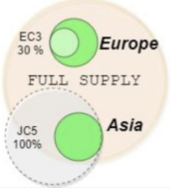
Control for Shield-A

Control for Shield-B

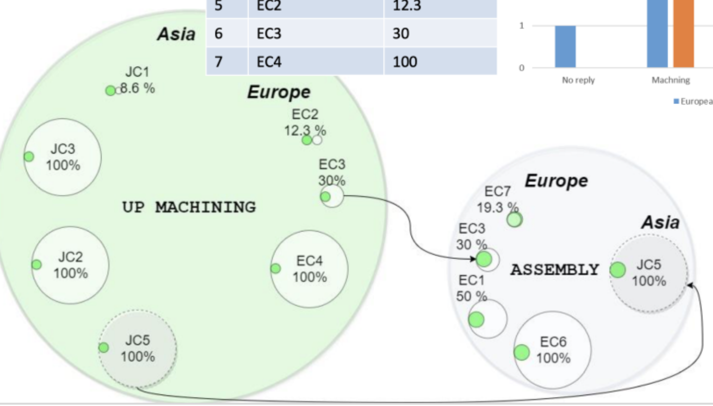
Companies distribution (survey results)

Nr	Company	Volume (%)
1	JC1	8.6
2	JC2	100
3	JC3	100
4	JC5	100
5	EC2	12.3
6	EC3	30
7	EC4	100





Nr	Company	Volume (%)
1	JC5	100
2	EC3	30



Nr	Company	Volume (%)
1	EC1	50
2	EC3	30
3	EC6	100
4	EC7	19.3
5	JC5	100

11

SC solenoid for HiEff klystrons

CERN – EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CLIC – Note – 1160

PERFORMANCE OF MgB$_2$ SUPERCONDUCTOR DEVELOPED FOR HIGH-EFFICIENCY KLYSTRON APPLICATIONS

H. Tanaka[3], T.Suzuki[3], M. Kodama[3], T. Koga[3], H. Watanabe[3], A. Yamamoto[1,2] and S. Michizono[2]

[1]CERN, Geneva, Switzerland
[2]KEK, Tsukuba, Japan
[3]Hitachi, Tokyo, Japan

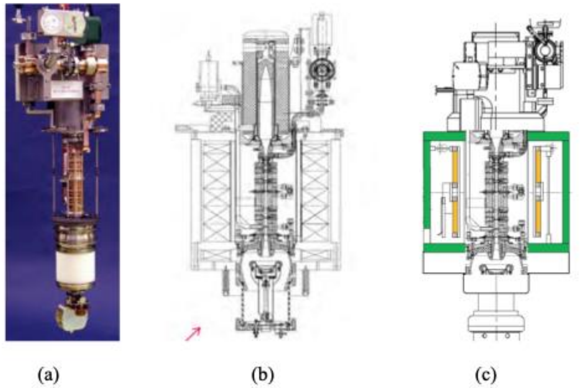


Fig. 3. (a) 12 GHz Klystron (main RF part), (b) Klystron assembled with conventional Cu solenoid, and (c) Klystrons assembled with a superconducting solenoid magnet.

CERN – EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CLIC – Note – 1161

DEVELOPMENT OF PROTOTYPE MgB$_2$ SUPERCONDUCTING SOLENOID MAGNET FOR HIGH-EFFICIENCY KLYSTRON APPLICATIONS

H. Watanabe[3], T. Koga[3], H. Tanaka[3], T. Wakuda[3], A. Yamamoto[1,2], S. Michizono[2], I. Syratchev[1], G. Mcmonagle[1], N. Catalan Lasheras[1] and S. Calatroni[1]

[1]CERN, Geneva, Switzerland
[2]KEK, Tsukuba, Japan
[3]Hitachi, Tokyo, Japan

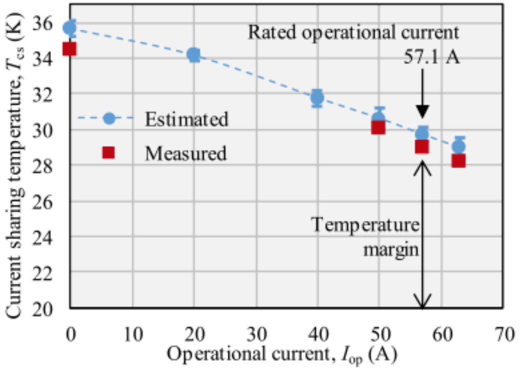


Fig. 7. Comparison of measured and estimated values of T_{cs}.

TABLE III
SPECIFICATIONS OF PRELIMINARY EXPERIMENTAL TEST COIL

PARAMETER	VALUE
Current (A)	57.1
Coil Inner diameter (mm)	165.7
Outer diameter (mm)	175.7
Length (mm)	53.6
Turn number (turns)	236
Inductance (H)	0.05
Stored energy (kJ)	0.08
Load factor (%)	21

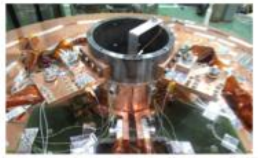


Fig. 10. Preliminary experimental test coil on test facility

Fig. 11. Prototype coils on test facility

Fig. 12. Finished magnet

CERN – EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CLIC – Note – 1159

APPLYING SUPERCONDUCTING MAGNET TECHNOLOGY FOR HIGH-EFFICIENCY KLYSTRONS IN PARTICLE ACCELERATOR RF SYSTEMS

A. Yamamoto[2], S. Michizono[2], W. Wuensch[1], I. Syratchev[1], G. Mcmonagle[1], N. Catalan Lasheras[1], S. Calatroni[1], S. Stapnes[1], H. Watanabe[3], H. Tanaka[3], S. Kido[3], T. Koga[3], Y. Koga[3] and K. Takeuchi[3]

[1]CERN, Geneva, Switzerland
[2]KEK, Tsukuba, Japan
[3]Hitachi, Tokyo, Japan

Final integrated tests at CERN
to be done (Covid affected)

ATF2-3 for nanobeams

- ATF2 work has continued (affected by Covid)
- AFT2 analysis – PhD students, some at CERN – also
- AFT2 review in September (extract from draft report on the left)
- ATF3 planning started
- In all cases with CERN involvement

Scientific results at ATF/ATF2

The committee has been impressed on outstanding and unique results achieved in ATF/ATF2:

- The smallest spot size, 40 nm, in any accelerators.
- Intra-train bunch orbit feedback (FONT).
- Vertical emittance in the ring, 4 pm, smallest at the beginning of the century.

The committee also applauds pioneering developments on various accelerator components:

- Fast extraction kickers with rise/fall time less than 3 ns
- Laser wires measuring 1 μm beam size
- Cavity BPMs with 20 nm resolution
- Single- and multi- OTR/ODR beam profile monitors

Some of these devices have been spread to other accelerators including CERN PS and light sources.

Educating graduate students and young scientists under international collaboration was another achievement of ATF, which is the best project at KEK in this aspect.

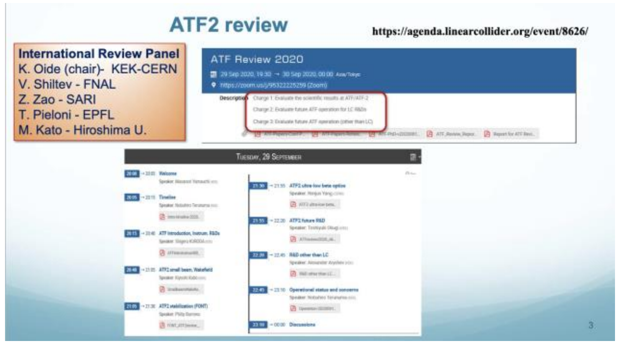
Future ATF operation for LC R&Ds

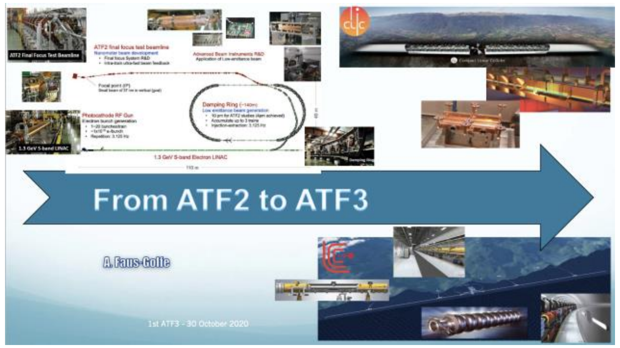
The committee recognizes that the achievements at ATF/ATF2 have already verified the minimum technical feasibility on the beam focusing and control for the ILC. However there will be a number of possibilities for further extensions to investigate:

- intensity dependent effects on the spot size
- optical aberrations, esp. with smaller horizontal β^*
- beam halo and collimation
- even smaller spot sizes with higher chromaticities

Besides the studies on the beam spot, the committee notices some possibilities of ATF to explore other components which will benefit the ILC preparation:

- polarized electron source, transport, and storage in the damping ring.
- beam collimation study using fancy devices such as using a laser or another beam.
- beam feedback within one turn of the ring circulation to simulate a fast feedback at the extraction of the ILC DR





LC 2021-25 at CERN after ESPP

Three main priorities:

1. Maintain CLIC as option for a Higgs/top machine for CERN – pursue High Gradient R&D
    - Concentrate on key technologies:
        - High gradient primarily (design, constr., tests) – also the key to all applications in research, medical and industrial accelerators (with high relevance for many coll. partners)
        - Nanobeams/luminosity and maintaining capabilities for start-to-end simulations
        - Drive-beam (in particular high eff klystrons – L band, some design work for structures)
    - Encourage collaboration activities where possible - fulfill commitments (collaboration agreements, EU projects – ARIES, CompactLight, I-FAST, KT agreements)
2. Make sure CLIC technology investments are exploited in compact medical and industrial accelerators where possible, with (as before mostly) external funding – enabled by the High Gradient Technology
3. Coordinate common CLIC/ILC activities - from LCC to ILC Development Phase activities, and CERN LC/KEK common activities in next phase related to ILC

Additional: "Coordinate" with other CERN acc. R&D activities (Hi-Eff klystrons , injectors with AWAKE, normal temp acc. cavities with RFQ and muon cooling designs, CLEAR, possibly PBC, SCRF and other expertise wrt ILC) – transfer/combine knowledge and resources

MTP text and goals 2021
(in red coll. areas with KEK)

After the ESPP submissions and during the coming years the focus will remain on core technology development and spread making use of existing facilities (High Gradient Test Stand and the CLEAR beam facility), optimising X-band components, and efficient use of the abovementioned collaborations with laboratories and universities using the technology.

The use of the CLIC technology - primarily X-band RF, associated components and nano-beams - in compact medical, industrial and research accelerators in many of the CERN Member States has become increasingly important development and test grounds for CLIC, and is destined to grow further. An EC supported design study with 24 partners pursue the use of the technology in future FELs facilities (CompactLight).

On the design side the parameters for running at multi-TeV energies, with X-band or other RF technologies, will be studied further, in particular with energy efficiency guiding the designs.

International Linear Collider (ILC) studies are supported through combined working groups (beam-dynamics, positrons, etc.) and co-operation with KEK for specific technology developments and ATF2. The future of the ILC focused part of linear collider activities will depend on the progress of the ILC project in Japan, primarily exploiting the commonalities between CLIC and ILC, common R&D studies between CERN and KEK, and European capabilities related to ILC technologies, inside and outside CERN.

- Optimise and develop the X-band core-technology by exploiting the existing experimental facilities, the High Gradient test stands, for testing and verifications of prototypes made within the collaboration;
- Maintain linear collider and linac design capabilities;
- Continue High Efficiency klystron optimisation in a coordinated effort with other studies and projects at CERN with similar needs;
- Continue high gradient studies, using the CLEAR facility, including among others wakefields, instrumentation for nano-beams, medical accelerators based on the technology;
- Follow up with collaborators the many smaller projects outside CERN where X-band technology is used – for medical, industrial and research linacs, providing very relevant effort/studies for CLIC, including industrial capability build up;
- Planning for European activities within ILC; in particular participate in defining the project's preparation phase activities, in case of further positive statements from Japan about hosting the project.

ICFA

ILC International Development Team

Executive Board

Americas Liaison	Andrew Lankford (UC Irvine)
Working Group 2 Chair	Shinichiro Michizono (KEK)
Working Group 3 Chair	Hitoshi Murayama (UC Berkeley/U. Tokyo)
Executive Board Chair and Working Group 1 Chair	Tatsuya Nakada (EPFL)
KEK Liaison	Yasuhiro Okada (KEK)
Europe Liaison	Steinar Stapnes (CERN)
Asia-Pacific Liaison	Geoffrey Taylor (U. Melbourne)

Working Group 1
Pre-Lab Setup

Working Group 2
Accelerator

Working Group 3
Physics & Detectors

IDT overall and WG1:

- Until end 2021, early 2022
- Prepare a proposal for the organization and governance of the ILC Pre-Lab (2022-25)
- Prepare the work and deliverables of the ILC Pre-laboratory and workout a scenario for contributions with national and regional partners
- Understand what is needed to get the Pre-lab started (constraints and opportunities)

- As European Liaison: Focus on European planning for Pre-lab participation (the following slides concentrate on CERN-KEK)

CERN – KEK agreement – being signed

CERN will facilitate the European participation in the work during the transition to the Pre-Lab Phase; including working groups on Pre-Lab preparation, accelerator and facility, and physics and detectors.

CERN will coordinate the European contributions to the Team's common fund, as well as the in-kind contributions to the tasks supported by the common fund during the preparation of the Pre-Lab Phase. The CERN office at KEK (set up under Appendix 10) will, as one of its tasks, provide administrative support to the European efforts related to transition to the Pre-Lab Phase.

The Parties will continue, or, as the case may be, undertake, collaborative work in studies related to:

- the accelerator's beam-delivery system and the Accelerator Test Facility 2 (ATF2) (as set out in the 2009 Agreement on Collaborative Work and Appendix 13);
- high gradient acceleration for linear colliders;
- high efficiency klystrons (as set out in Appendix 23);
- detector, physics and software (as set out in Appendix 8);
- cryogenics systems, beam-dumps, superconducting radiofrequency (SC RF) module components and technologies, civil engineering (all areas where CERN has provided technical advice as part of the LCC collaboration); and
- other areas of common interest (e.g.: positron production and beam-dynamics) and/or information exchange related to common challenges (e.g.: costing methodology and power reduction studies).

Any existing collaborative work referred to above will continue to be executed under its relevant Appendix.

APPENDIX 24

to

The Agreement on Collaborative Work (ICA-JP-0103)

between

THE HIGH-ENERGY ACCELERATOR RESEARCH ORGANIZATION (KEK)

and

THE EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH (CERN)

concerning

The work of the ILC International Development Team to facilitate the transition into the "Pre-Lab Phase"

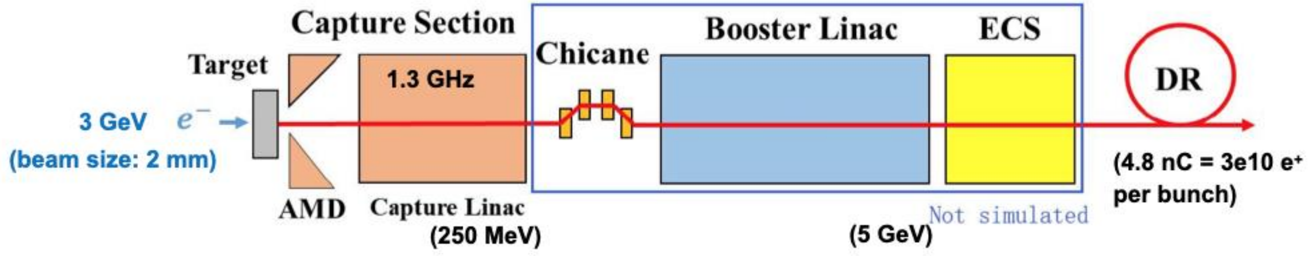
2020

Topic	CLIC – ILC communality	Other	Status wrt ILC and KEK
CE and Cryo	CE common	All future project	WG2 reps from CERN
ATF2(3), BDS, beamdynamics, instrumentation and beam-elements related	Common	Other nanobeam projects	Participate in ATF3 study – BDS optimisaton (slide shown)
Positrons	Common for e-driven	All e+e- colliders	See slide below, WG2 rep. from CERN
Damping Rings	Common	All low emittance rings	Possible effort (performance studies, design and also kicker for CLIC relevant)
Hi-Eff klystron	Common (L-band)	FCC, CEPC etc	See slide below (also SC solenoid work mentioned above)
SCRF cavities	For ILC	SCRF generally	Stay informed, EB welding studies, and possibly long term Nb3Sn studies (slide below)
Couplers	For ILC	SCRF generally	Possible design effort, also common work in the past
Beam dump	Common	LHC/FCC/muon ..	Advisory
Physics and Detectors	Common	Higgs factories	Some common tools, not defined longer term
X-band	For CLIC	NC linacs	Test-stands and industry (slide shown)
CERN – KEK office, agreements, WEB pages, LCWS,	Partly common	-	LC project office working with KEK

Positrons

Code validation: ILC reproduction

- ILC positron source (e-driven) quite similar as CLIC, which can be used to cross-check and validate our code



e^+ yield	Software	After target	After AMD	After Capt. Sect.	DR accepted
ILC	Geant4	7.13	5.09	1.94	1.03
Reprod.	Geant4+RF_Track	7.07	4.48	1.97	1.11
Diff.		1%	12% *	2%	8%

* Difference after AMD due to particle interactions in Geant4. Otherwise, it is reduced to 2%

2.4 nC e^- bunch	ILC	Reprod.	Diff.
PEDD (in target) [J/g]	22.0	23.7	8%

Good agreement!

Positron production modelling and target, AMD optimization

Common Project with Shandung University

Evaluating next stages with KEK (SuperKEKb and ILC) and Orsay and PSI (FCC-ee)

Target studies and simulation studies for CLIC are very relevant – and visa versa, example on the left where ILC studies are used as code validation for CLIC

HiEff klystron for CLIC and ILC - and CERN office at KEK

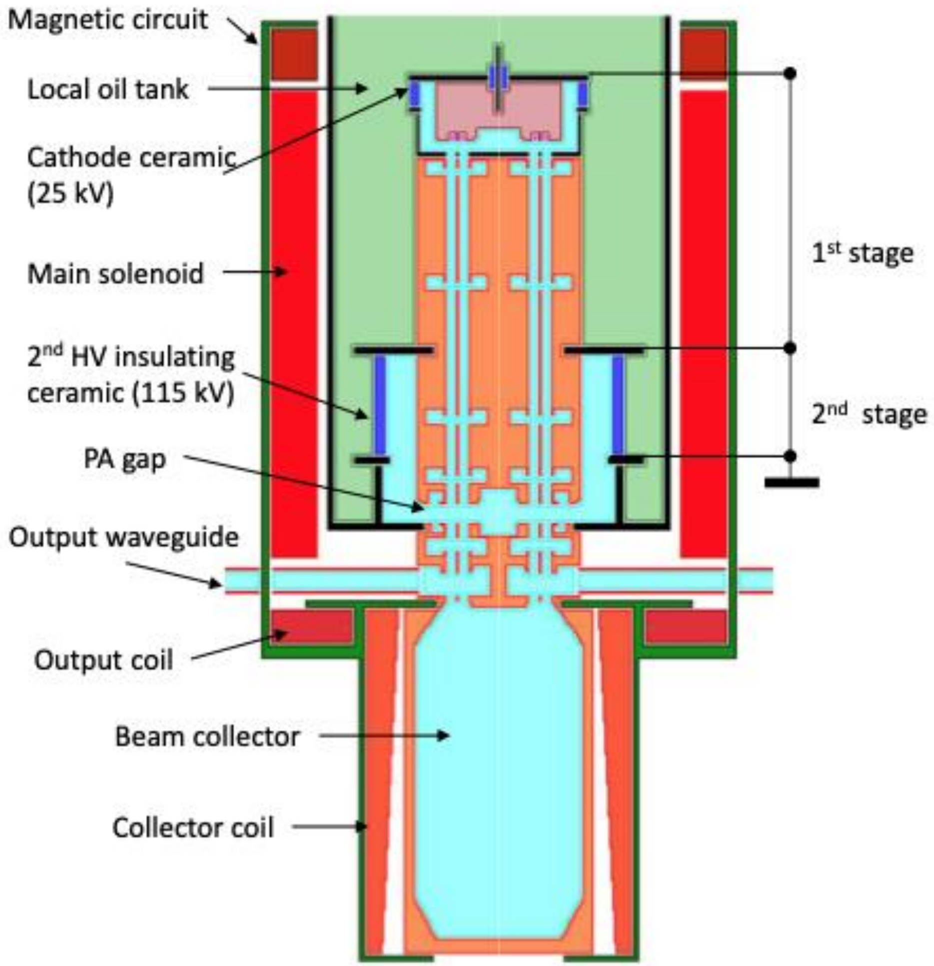


Photo of the room

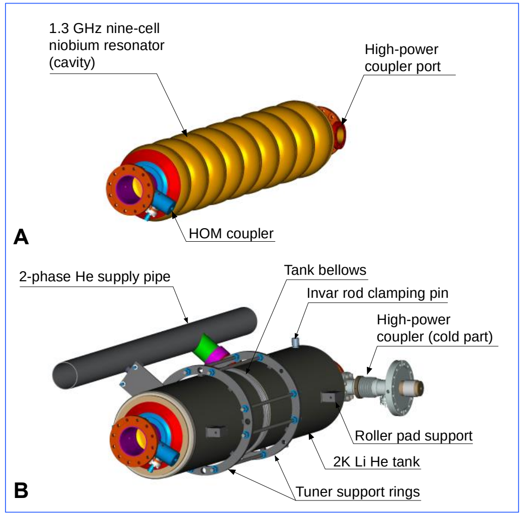
Bright and clean room for office users.

Klystron design mature, to be completed
Can we find common resources to prototype ?

SCRF

N. Walker

1.3 GHz 9-Cell Cavities/Resonators



Ultra-Clean Environment Required for assembly

Solid high-grade niobium
- RRR ≥300

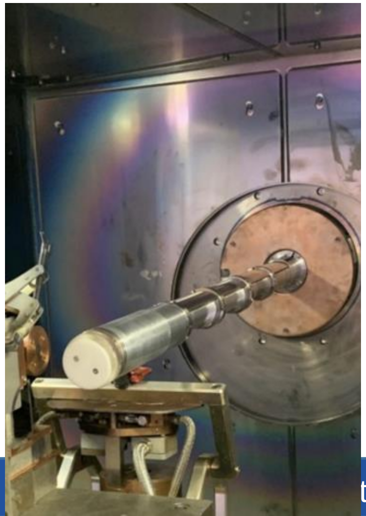
Mechanical fabrication
- deep drawing
- electron-beam welding

Surface preparation
- electro-polishing
- High-pressure rinsing
- 800 deg C bake

Following EXFEL cavity "biuld-to-print" Specification, as reference

Cavity package:
- HOM couplers (x2)
- Magnetic shield
- High-power input coupler
- Ti-Nb Helium tank (cryostat)
- Mechanical tuner

A. Yamamoto: 2013.2.6 SCRF)Cost)Overview



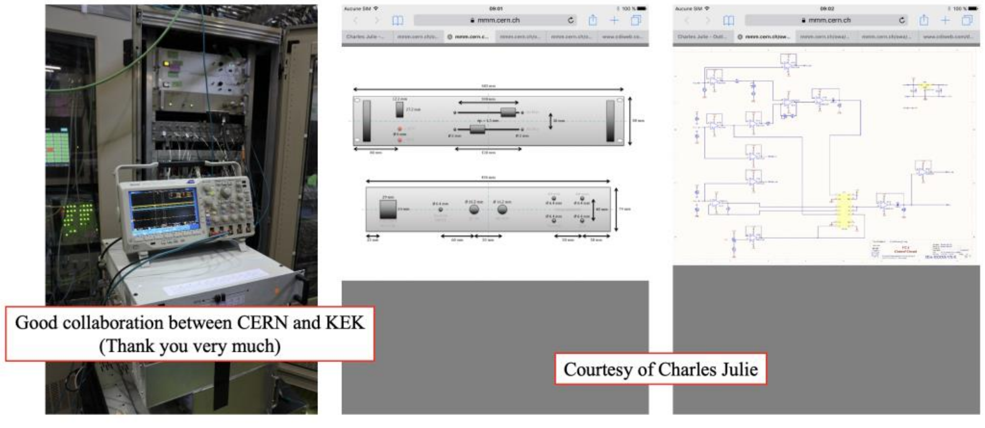
SCRF studies at CERN in contact with ILC

Collaboration on "inside" EB welding for cavities (fabrication techniques)

Possible coupler design – also earlier work in this area (CERN contributions to coupler RF test-stand, picture below from 2016)

Possible common interest in longer term R&D (Nb3Sn)

Auto-conditioning Module by CERN



We connected RF_{in}, RF_{out} and Vacuum output (only one ch.) to this module.

IDT-WG2 organization

Bi-weekly *Tuesday* meeting: Sep.22, Oct. 6, 20,…

IDT WG2
Shin Michizono (Chair)
Benno List (Deputy)

https://agenda.linearcollider.org/category/256/

SRF
Bi-weekly Tuesday Oct.13,27,…

Yasuchika Yamamoto	***KEK***
Nuria Catalan	CERN
Dimitri Delikaris	CERN
Rongli Geng	JLAB
Hitoshi Hayano	KEK
Bob Laxdal	Triumf
Matthias Liepe	Cornell
Peter McIntosh	STFC
Olivier Napoly	CEA
Sam Posen	FNAL
Robert Rimmer	JLAB
Marc C. Ross	SLAC
Akira Yamamoto	KEK

DR/BDS/Dump
Bi-weekly Tuesday Oct.13,27,…

Toshiyuki Okugi	***KEK***
Karsten Buesser	DESY
Philip Burrows	U. Oxford
Angeles Faus-Golfe	LAL
Jenny List	DESY
Thomas Markiewicz	SLAC
Brett Parker	BNL
David L. Rubin	Cornell
Nikolay Solyak	FANL
Luis Garcia Tabares	CIEMAT
Nobuhiro Terunuma	KEK
Glen White	SLAC
Kaoru Yokoya	KEK

Charges of Sub-groups

- Discuss and coordinate the topics for
  - technical preparation (remaining topics) at Pre-lab
  - preparation for mass production at Pre-lab
  - possible schedule at Pre-lab
  - international sharing candidates of these activities
- Report to the IDT-WG2

All members belong to some sub-group(s).

Sources
Bi-weekly Monday Oct.12,26,..

Kaoru Yokoya	***KEK***
Jim Clarke	STFC
Steffen Doebert	CERN
Joe Grames	JLAB
Hitoshi Hayano	KEK
Masao Kuriki	U. Hiroshima
Benno List	DESY
Gudrid Moortgat-Pick	U. Hamburg

Civil engineering

Nobuhiro Terunuma	***KEK***
John Andrew Osborne	CERN
Tomoyuki Sanuki	U. Tohoku

Conclusion

- The ESPP and ILC IDT define – and motivate – collaborative studies, the challenge is to find the appropriate combinations of challenges and possibilities within available resources

- The collaborative possibilities for LC’s are not limited to CLIC – ILC, technical expertise and experience from LHC/HL LHC in many cases very relevant (examples cryo, SCRF ..)

- Work goes on in many areas as shown

Slides/plots and pictures from many colleagues in CLIC and ILC – many thanks